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Zhou et al.

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(54) **INTEGRATED IF SAW FILTER IN BASEBAND DIGITAL DESIGN FOR ANALOG TV (OR HYBRID) TUNER**

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(51) **Int. Cl.**

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H04N 5/44	(2011.01)
H04N 21/438	(2011.01)
H04N 5/60	(2006.01)

(52) **U.S. Cl.**

CPC . ***H04N 5/50*** (2013.01); ***H04N 5/44*** (2013.01); *H04N 5/60* (2013.01); ***H04N 21/4383*** (2013.01)

(58) **Field of Classification Search**

USPC 348/660

See application file for complete search history.

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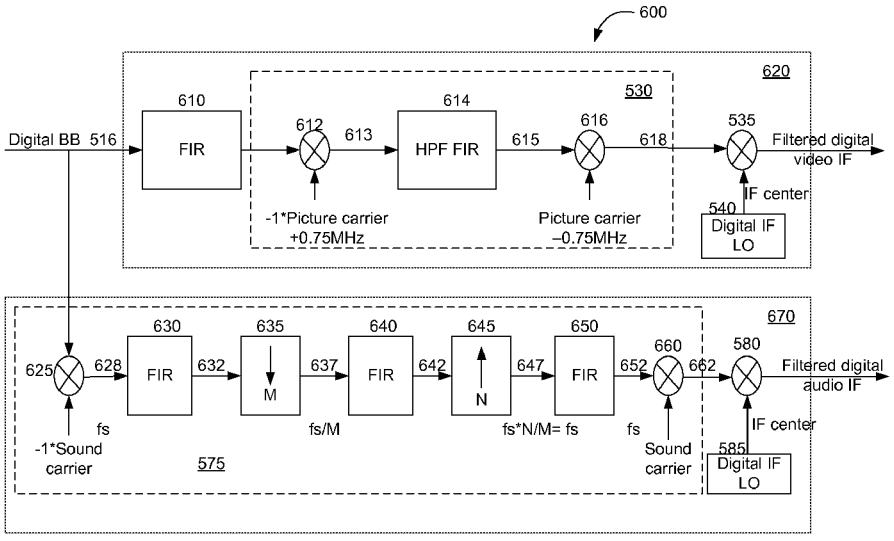
(57) **ABSTRACT**

A filter for processing a digital TV composite signal having a video component and an audio component includes a digital video filter and a digital audio filter. The digital video filter includes a lowpass finite impulse response (FIR) filter, an up-mixer, an asymmetric filter for compensating a Nyquist slope of the video component, and a down-mixer connected in this order. The digital audio filter includes an audio down-mixer, a decimated FIR filter, an enhancing FIR filter, an interpolated FIR filter, and an audio up-mixer. These components are connected in series. Optionally, the decimating FIR filter is decimated by an integer decimation factor M, and the interpolated FIR filter is interpolated by an integer factor N. The integer M and N may have the same value.

14 Claims, 11 Drawing Sheets



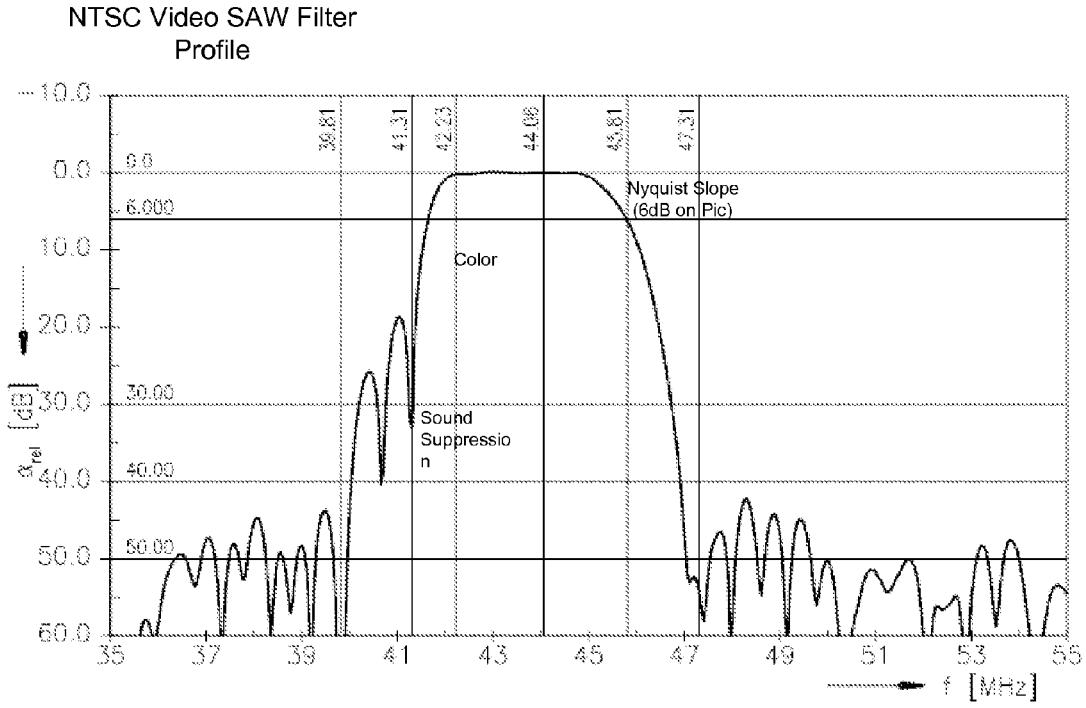

NTSC Video SAW Filter Profile
-10.0
0.0
10.0
20.0
30.0
40.0
50.0
60.0
0.0
6.000
30.00
40.00
50.00
36.81
41.31
42.23
44.06
45.81
47.31
Nyquist Slope (6dB on Pic)
Color
Sound Suppressio n
35
37
39
41
43
45
47
49
51
53
55
f [MHz]

FIG. 1A

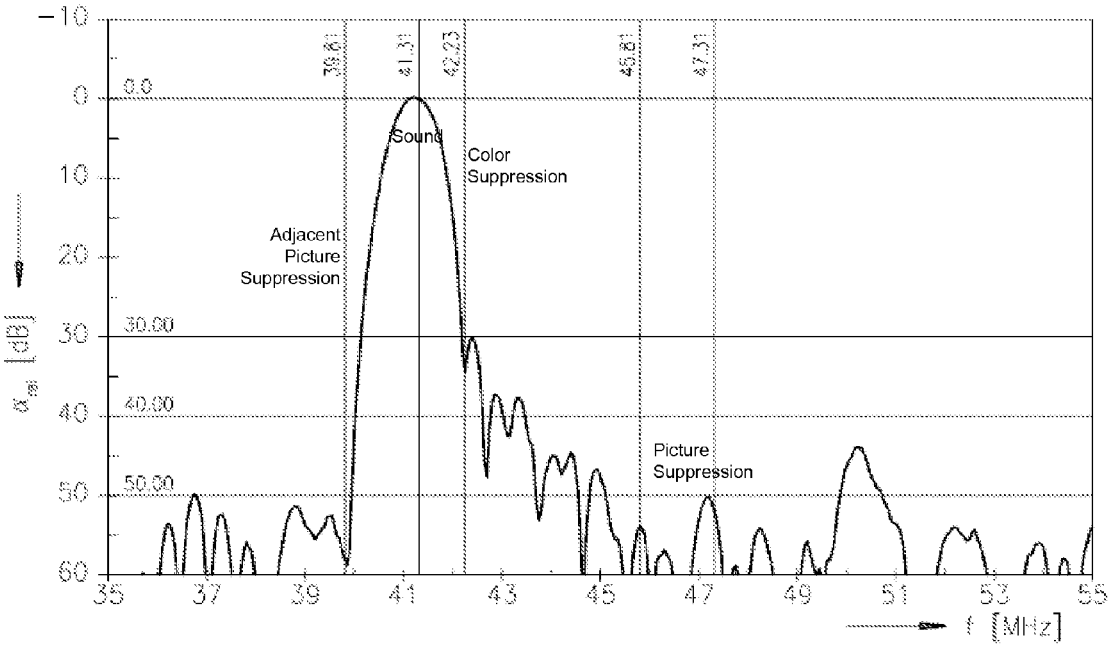

−10
0
10
20
30
40
50
60
0.0
30.00
40.00
50.00
39.61
41.31
42.23
45.81
47.31
Sound
Color
Suppression
Adjacent
Picture
Suppression
Picture
Suppression
35
37
39
41
43
45
47
49
51
53
55
f [MHz]

FIG. 1B

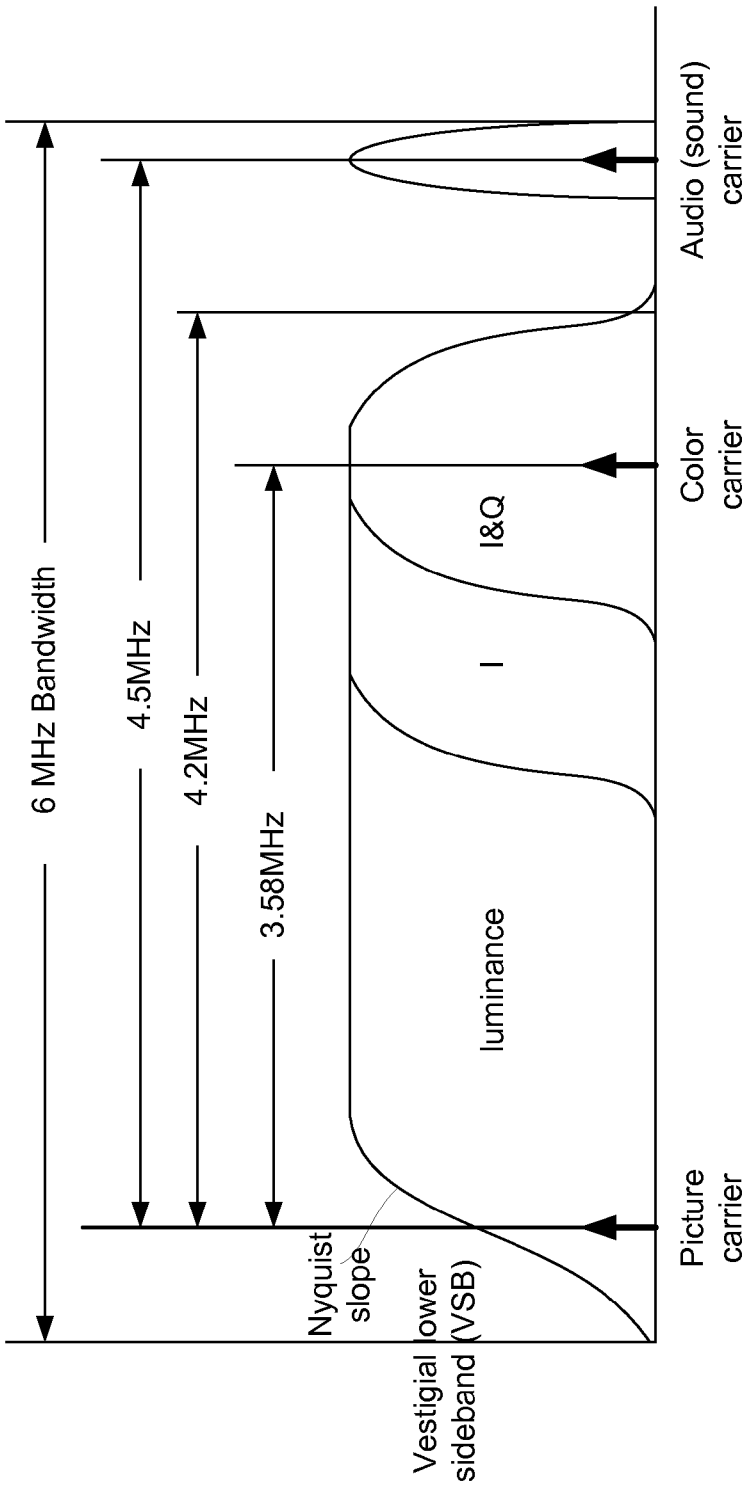

6 MHz Bandwidth
4.5MHz
4.2MHz
3.58MHz
Audio (sound) carrier
Color carrier
Picture carrier
I&Q
I
luminance
Nyquist slope
Vestigial lower sideband (VSB)

FIG. 2

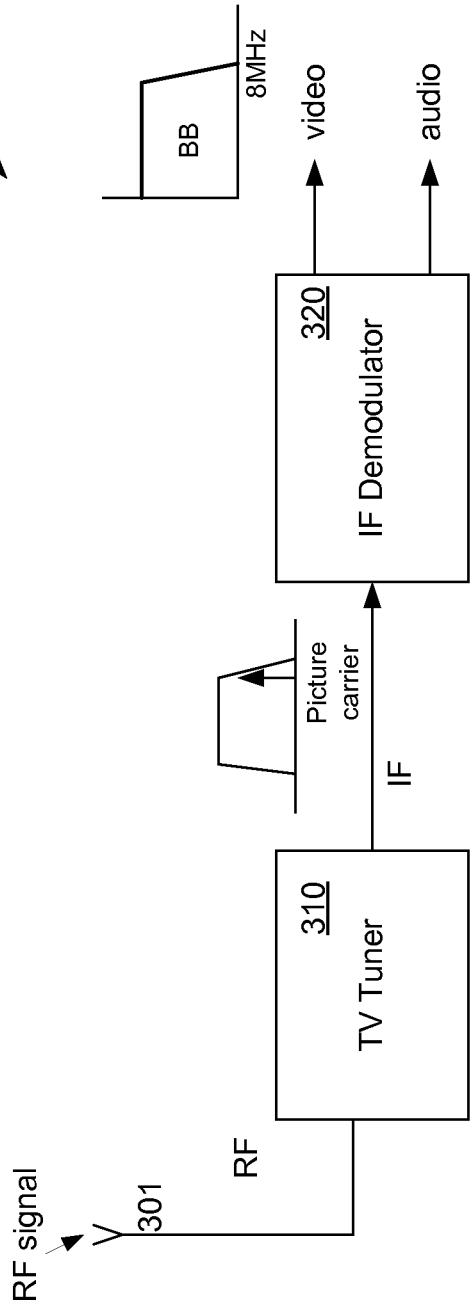


FIG. 3 (Prior Art)

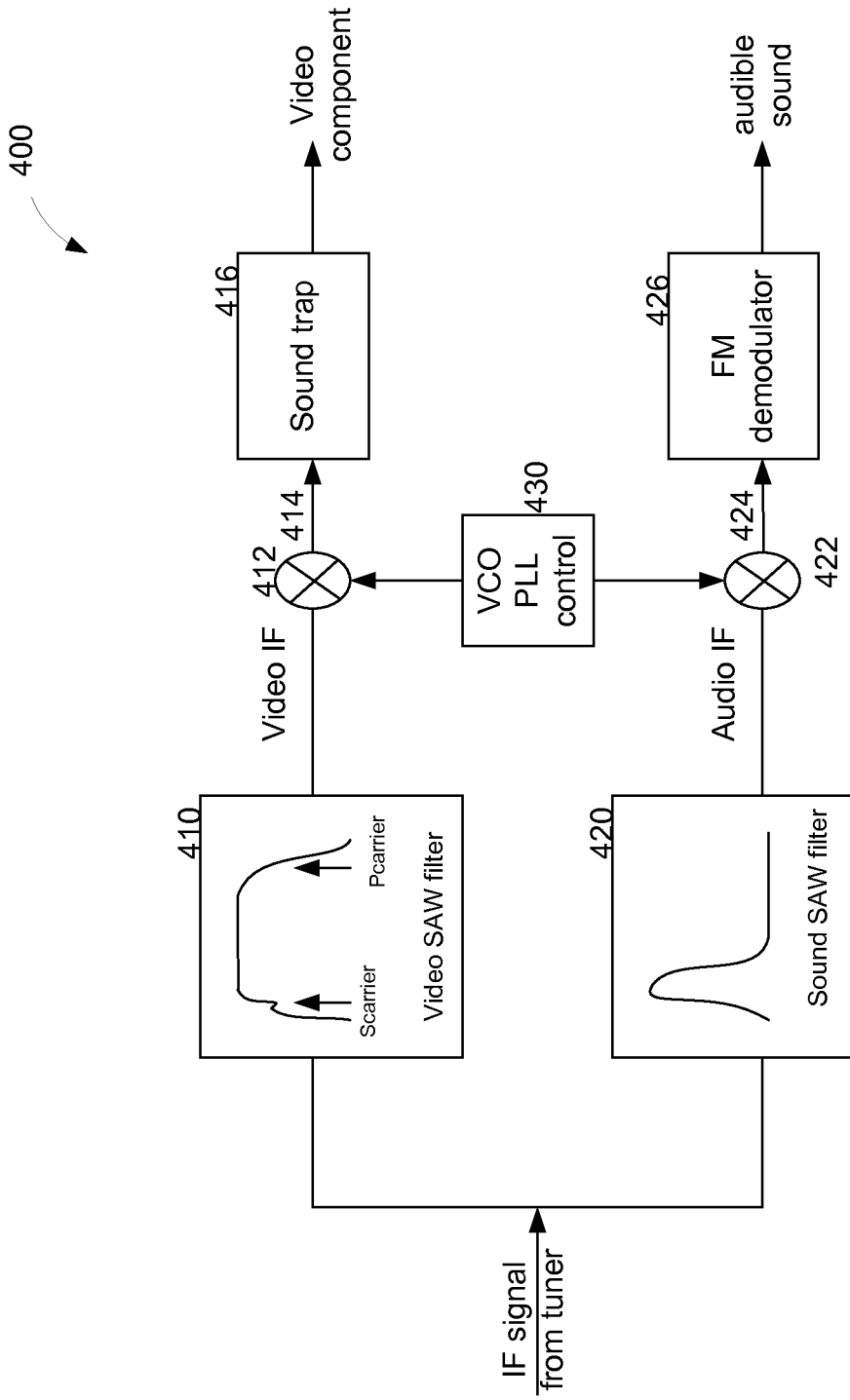


FIG. 4 (Prior Art)

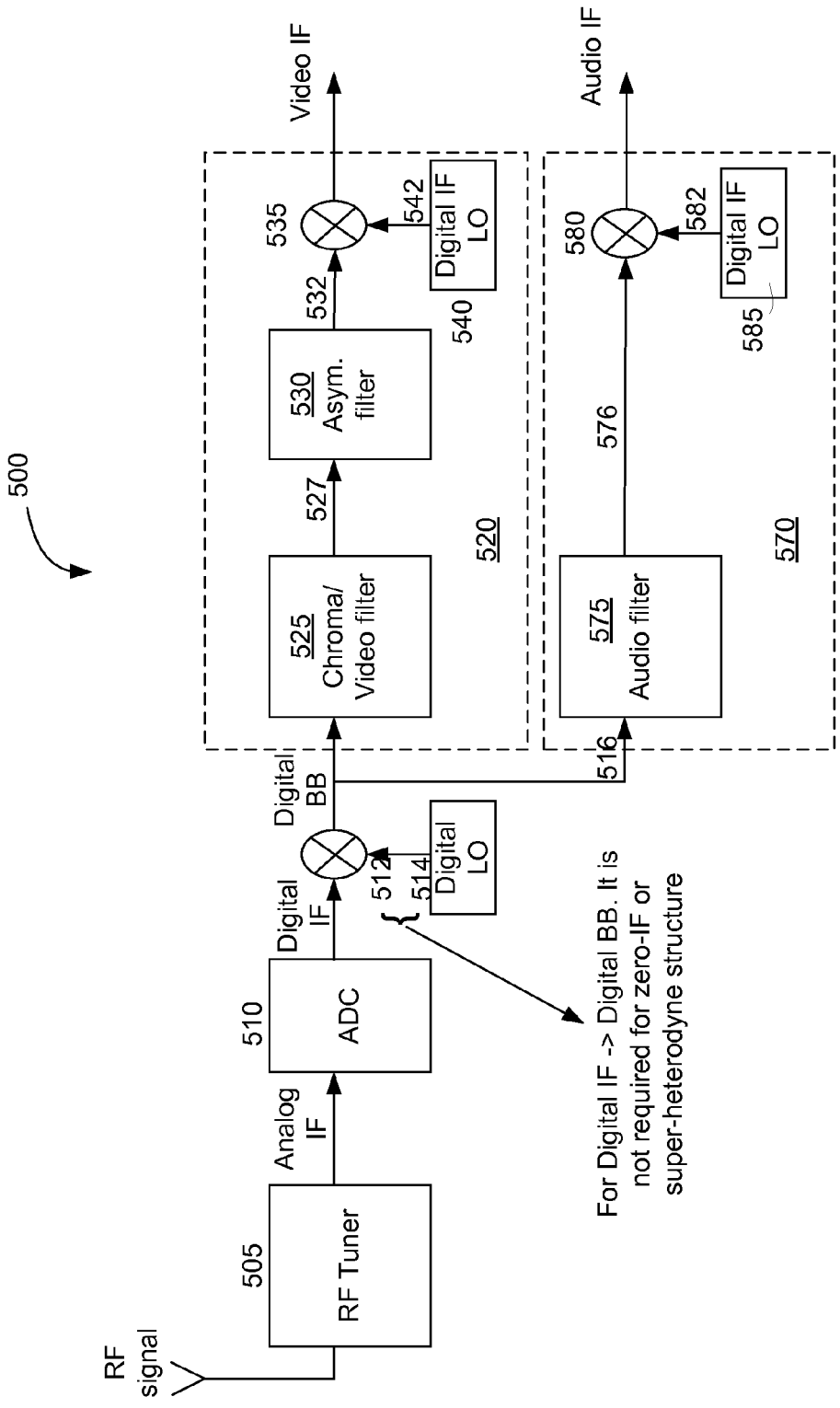

500
RF signal
505
RF Tuner
Analog IF
510
ADC
Digital IF
512
514
Digital LO
Digital BB
516
520
525
Chroma/ Video filter
527
530
Asym. filter
532
535
542
Digital IF LO
540
Video IF
570
575
Audio filter
576
580
582
Digital IF LO
585
Audio IF
For Digital IF -> Digital BB. It is not required for zero-IF or super-heterodyne structure

FIG. 5A

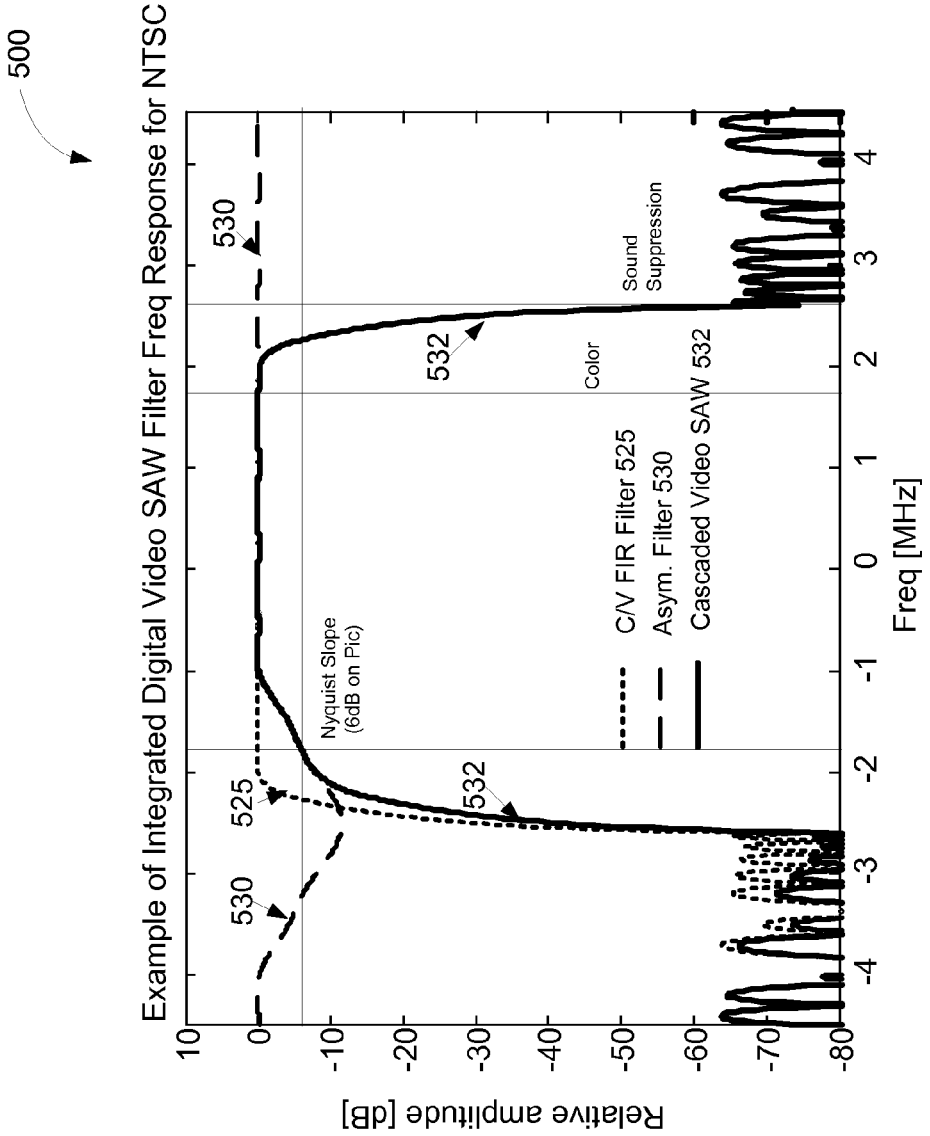

500
Example of Integrated Digital Video SAW Filter Freq Response for NTSC
Relative amplitude [dB]
Freq [MHz]
10
0
-10
-20
-30
-40
-50
-60
-70
-80
-4
-3
-2
-1
0
1
2
3
4
530
525
532
532
530
Nyquist Slope
(6dB on Pic)
Color
Sound
Suppression
C/V FIR Filter 525
Asym. Filter 530
Cascaded Video SAW 532

FIG. 5B

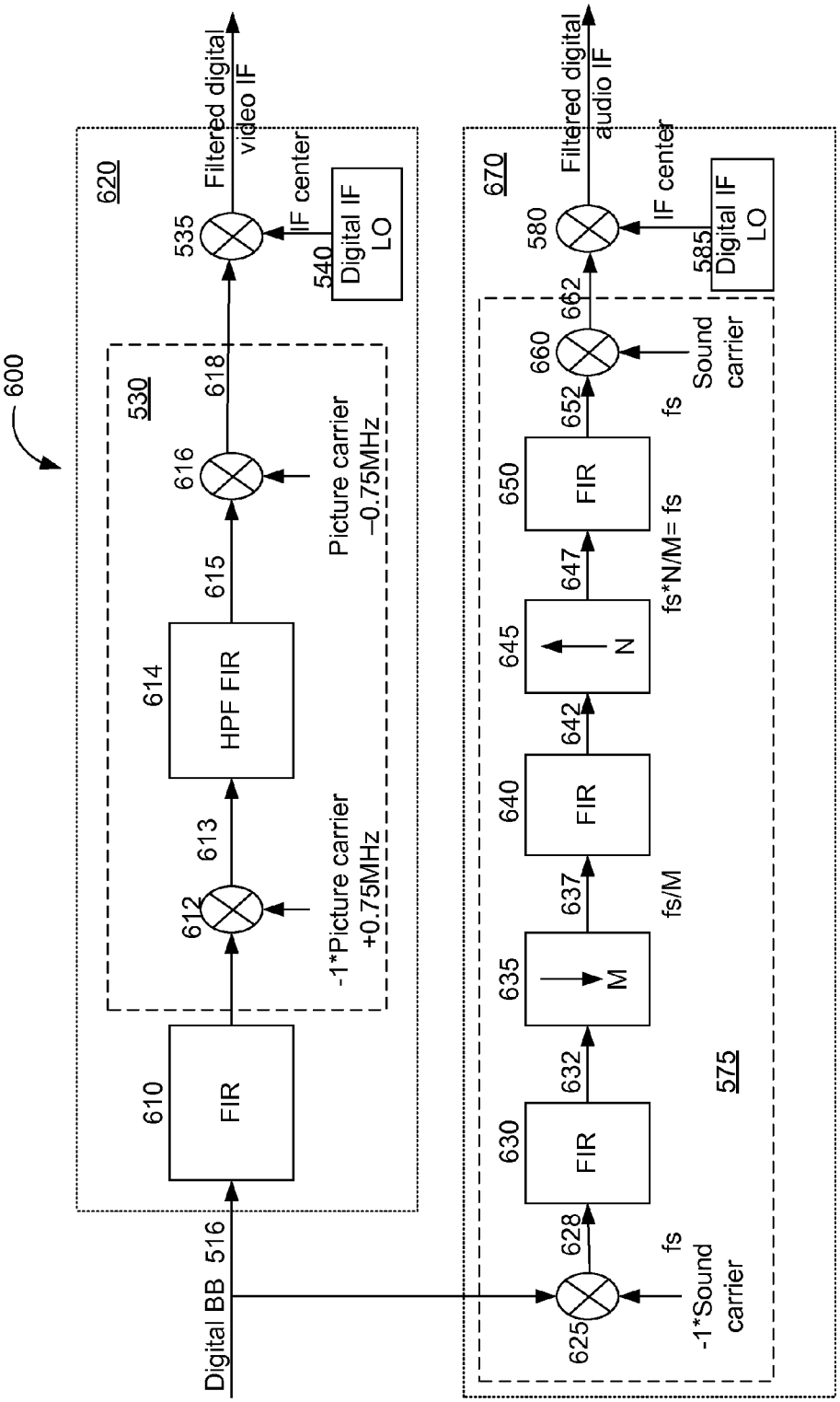

600
620
530
610
FIR
612
613
-1*Picture carrier
+0.75MHz
614
HPF FIR
615
616
618
Picture carrier
–0.75MHz
535
Filtered digital
video IF
IF center
540
Digital IF
LO
Digital BB 516
625
628
fs
-1*Sound
carrier
630
FIR
632
635
M
637
fs/M
640
FIR
642
645
N
647
fs*N/M= fs
650
FIR
652
660
662
fs
Sound
carrier
670
575
580
Filtered digital
audio IF
IF center
585
Digital IF
LO

FIG. 6A

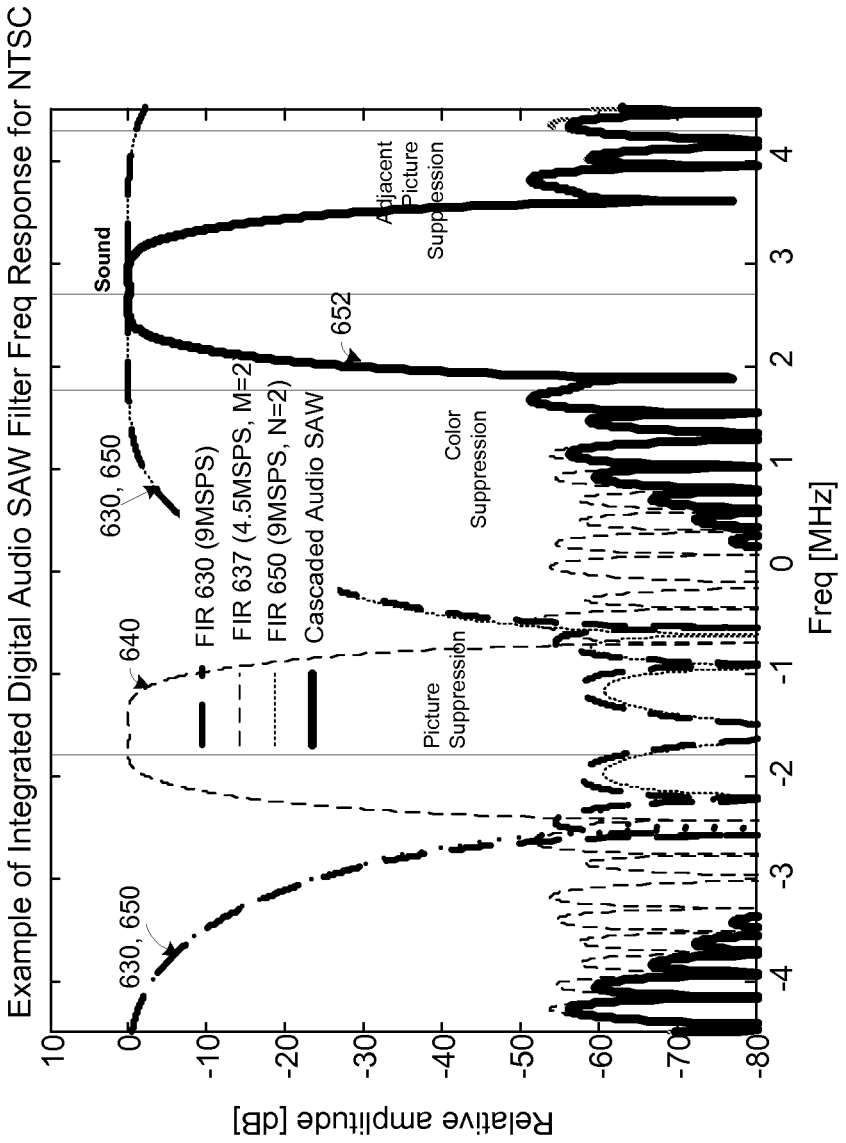

Example of Integrated Digital Audio SAW Filter Freq Response for NTSC
Relative amplitude [dB]
Freq [MHz]
FIR 630 (9MSPS)
FIR 637 (4.5MSPS, M=2
FIR 650 (9MSPS, N=2)
Cascaded Audio SAW
630, 650
640
652
Sound
Picture Suppression
Color Suppression
Adjacent Picture Suppression

FIG. 6B

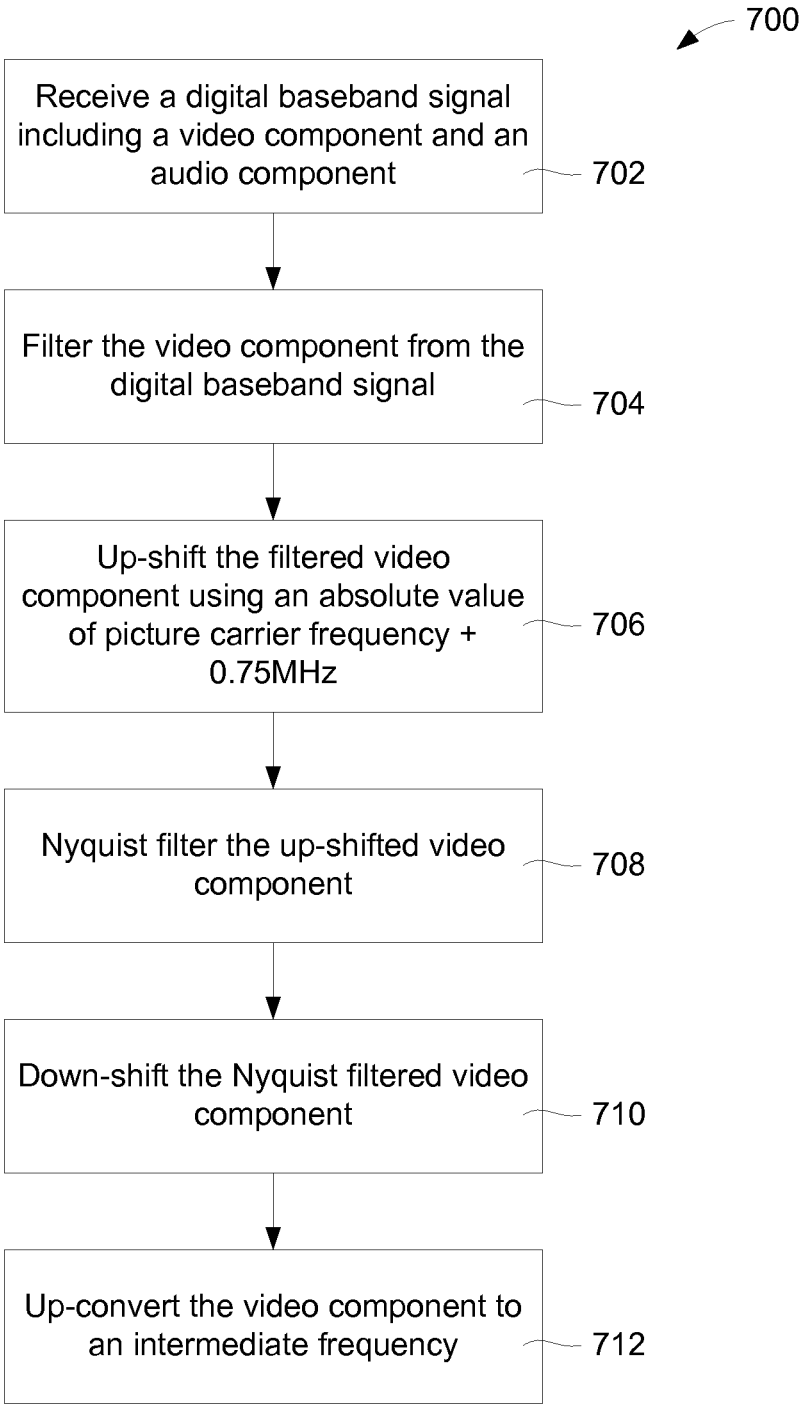

700
Receive a digital baseband signal including a video component and an audio component
702
Filter the video component from the digital baseband signal
704
Up-shift the filtered video component using an absolute value of picture carrier frequency + 0.75MHz
706
Nyquist filter the up-shifted video component
708
Down-shift the Nyquist filtered video component
710
Up-convert the video component to an intermediate frequency
712

FIG. 7

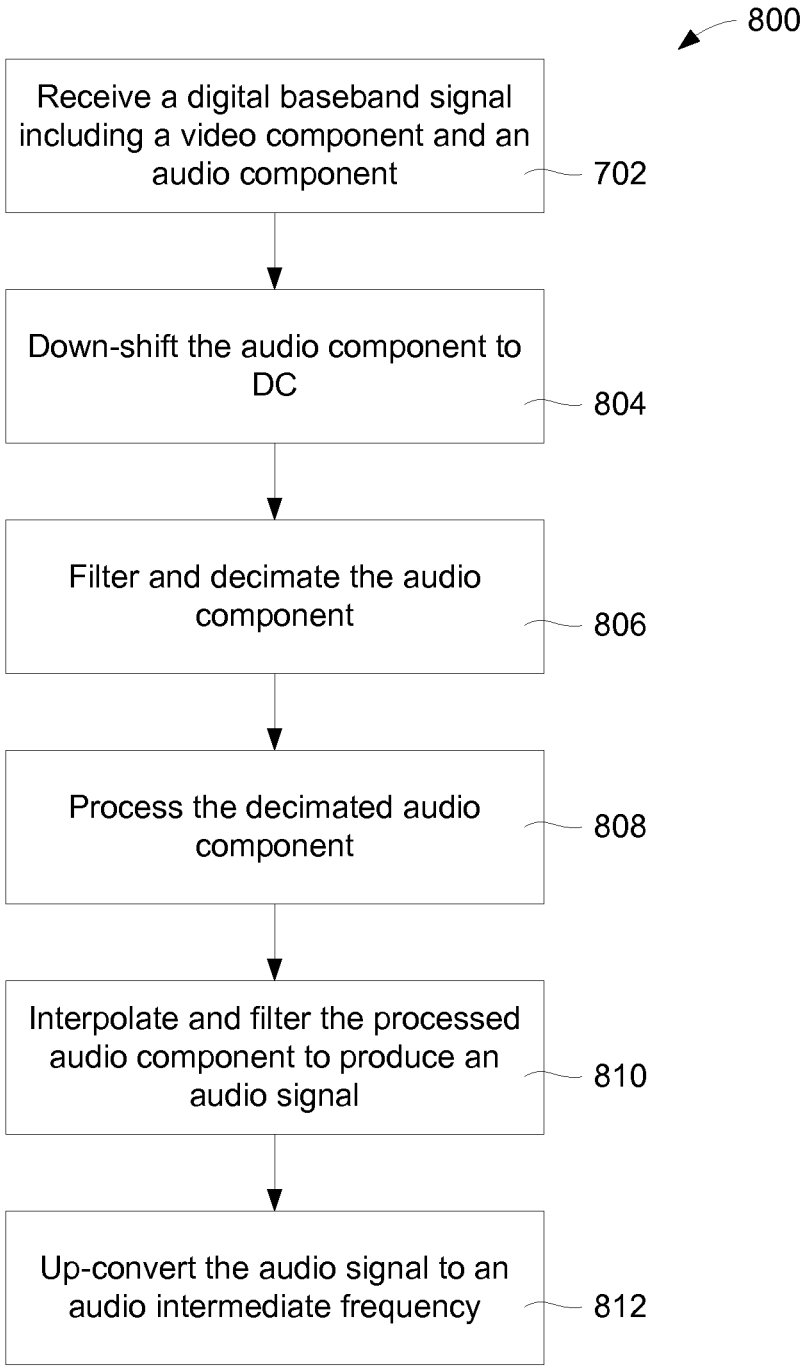

800
Receive a digital baseband signal including a video component and an audio component
702
Down-shift the audio component to DC
804
Filter and decimate the audio component
806
Process the decimated audio component
808
Interpolate and filter the processed audio component to produce an audio signal
810
Up-convert the audio signal to an audio intermediate frequency
812

FIG. 8

INTEGRATED IF SAW FILTER IN BASEBAND DIGITAL DESIGN FOR ANALOG TV (OR HYBRID) TUNER

CROSS-REFERENCES TO RELATED APPLICATIONS

The present application claims benefit under 35 USC 119 (e) of U.S. provisional application No. 61/263,271, filed Nov. 20, 2009, entitled "Integrated IF SAW Filter in Base-Band Digital Design For Analog TV (or Hybrid) Tuner," the content of which is incorporated herein by reference in its entirety.

BACKGROUND OF THE INVENTION

The present invention relates to a digital filter device and a method for processing TV composite signals, and more particularly to digital filters for processing an audio component and a video component of a TV composite signal.

The fundamental function of a video decoder is to separate the video component from the audio component. The separation of the video and audio components can be performed in multiple ways. Many separation methods have been implemented since the introduction of television.

A color television (TV) composite signal includes two basic components: the video component and the audio component. The video component further contains the luminance information, the chrominance information, and the synchronization information (Horizontal and Vertical Sync).

Television channels are grouped in multiple bands, such as low VHF band, high VHF band, and UHF band. These bands span from 40 MHz to 890 MHz. Within the frequency bands, adjacent channels are spaced at either 6 MHz or 8 MHz in most parts of the world.

For receiving a desired channel, a local oscillator of a TV receiver is tuned to a frequency so that after mixing, the desired or selected channel is produced at a preset intermediate frequency (IF) signal that is then further processed in a subsequent demodulator. IF demodulators typically employ surface acoustic wave (SAW) filters to condition the IF signal prior to extracting the video and the audio signals. The SAW filter rejects the energy bands associated with channels adjacent to the desired channel. The SAW filter provides a Nyquist slope bandpass response for the IF signal (see FIG. 1A). Since TV demodulators operate at either a 36 MHz or 44 MHz intermediate frequency, at least two SAW filters with center frequency at 36 MHz and at 44 MHz have to be used in order to support multi-standard TV signal reception.

Because a TV composite signal contains the luminance, chrominance and audio information, additional SAW filters for filtering the video component and audio component from the TV composite signal are required. Since different TV standards use different broadcast frequencies with different bandwidths, a traditional multi-standards TV receiver is required to have multiple different tuners equipped with video and audio filters for the decoders.

Further, even for one-standard (e.g. for one country) TV system, a demodulator requires to have at least two IF SAW filters, one for the video component and another one for the audio component in order to separate the video and audio components within the TV composite signal. The need of SAW filters not only requires a large area for layouts, but also increases the costs of the PCB bill of materials. For applications in handheld or wearable TV tuners, a small PCB layout area is considered especially critical. And the portability requirement imposes that TV tuners support multiple standards because, as consumers are now traveling to different countries around the world, they expect to receive local TV programs using their laptops, notebooks, smart phones, and other devices.

It can be seen that there is a need of a filter device and a method that can perform multi-standard channel filtering without resorting to the use of any mechanical IF SAW filters in order to reduce part count, cost, and size, and increase system reliability.

Accordingly, the present invention provides a technical solution to the problems discussed above, and that this solution can be economically integrated into a single electronic device using standard CMOS or any other integrated circuit processes.

BRIEF SUMMARY OF THE INVENTION

Embodiments of the present invention provide a filter device for processing a digital television composite signal that includes a video component and an audio component. Herein, the term "digital television composite signal" refers to a digitized version of an analog television composite signal that includes a digital video component and a digital audio component. The filter device includes an input terminal that is configured to receive the television composite signal and a first lowpass filter connected to the input terminal, the lowpass filter passes through the video component. The filter device further includes a video filter configured to receive the video component, the video filter contains a first mixer, a highpass filter, and a second mixer, which are connected in series, where the highpass filter is interposed between the first and second mixers. The filter device may additionally include a third mixer that frequency-shifts the audio component to DC (0 Hz) and a digital audio filter that passes through the audio component at DC. In an embodiment, the filter device may further include a video up-converter for up-converting the digitally filtered and processed video component onto a video intermediate frequency and an audio up-converter for converting the processed audio component to an audio intermediate frequency.

In an embodiment, the highpass filter of the video filter comprises an asymmetric filter for compensating for the Nyquist slope of the video component.

In another embodiment, the audio filter includes a decimating filter, a modifying filter, and an interpolating filter, that are connected serially in the given order. These three filters can be finite impulse response (FIR) filters and interposed between the third mixer and a fourth mixer. The third mixer downshifts the audio component of the television composite signal to DC by multiplying the audio component with a negative sound (or audio) carrier frequency, so that the audio component at DC can be filtered and decimated by the decimating filter. The decimated audio component is further processed in the modifying filter to further remove unwanted spectrum elements. And the interpolating filter interpolates and filters the modified audio components to provide an audio signal to an FM demodulator. In some circumstances, the audio signal may be up-converted to an audio intermediate frequency.

In an embodiment, a numerically control oscillator or a direct digital frequency synthesizer can provide the intermediate frequency for the video and audio up-converters. In other embodiments, direct digital frequency synthesizers may be used to produce positive and negative picture carrier frequencies and sound carrier frequencies. In some embodiments, filters of the video and audio filters comprise finite impulse response filters, each contains multiple digital taps; these taps are easily programmable for different analog TV standards.

The present invention also provides a method of processing a digital television baseband signal, the digital television baseband signal includes a video component and an audio component. The method includes receiving the digital television baseband signal and filtering the video component using a finite impulse response lowpass filter. The method further includes up-shifting the video component by a first frequency amount that corresponds to the picture carrier frequency. The up-shifted video component is then filtered with a Nyquist filter, which, in some embodiments, can be a highpass finite impulse response filter. The method includes down-shifting the Nyquist filtered video component by a second frequency amount to obtain a processed video signal, where the down-shifting cancels out the up-shifting; that is, the second frequency amount is substantially equal to the first frequency amount, but have a opposite sign so that their sum is substantially equal to zero. The method may further include up-converting the processed video signal to a video intermediate frequency.

In addition, the method includes down-shifting the audio component of the television baseband signal to DC to retrieve the audio component using a lowpass filter. The lowpass filter may be a FIR filter. The filtered audio component is then decimated and further processed with a subsequent filter. The processed audio component is then interpolated and filtered to produce a audio signal. In an embodiment, the method may include up-converting the audio signal to an audio intermediate frequency.

In an embodiment, down-shifting the audio component to DC includes multiplying or mixing the digital television baseband signal with a sound carrier frequency.

In an embodiment, it is an advantage of the present invention that all video and audio filters are FIR filters so that the entire receiving paths have a constant group delay.

It is an advantage of the present invention to provide a digital filter solution that is implementable in a single chip using any standard integrated circuit processes; the digital filter solution can also be easily programmed to adapt to different TV system standards using on-chip algorithms. In some embodiments, the algorithms of the digital filter can be updated or "patched" via a digital serial interface (e.g., I2C).

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention is described with reference to the accompanying drawings, in which:

FIG. **1**A is a frequency response of a conventional video SAW filter having an IF centered around 44 MHz for the NTSC system;

FIG. **1**B is a frequency response of a conventional NTSC audio SAW filter;

FIG. **2** is a TV composite signal including a picture carrier, a color carrier, and an audio carrier according to the NTSC specification;

FIG. **3** is a block diagram of a conventional TV tuner system including an IF demodulator;

FIG. **4** is a conventional block diagram showing the use of a video SAW filter and an audio SAW filter;

FIG. **5**A is a block diagram of a TV receiver system according to an embodiment of the present invention;

FIG. **5**B is an exemplary graph illustrating a frequency response of a video/chroma filter, an asymmetric filter, and the resulting frequency response according to an embodiment of the present invention;

FIG. **6**A is a simplified block circuit diagram of a TV receiver system according to an embodiment of the present invention; and

FIG. **6**B is an exemplary graph illustrating frequency response waveforms at different stages of a digital audio SAW filter according to an embodiment of the present invention.

FIG. **7** is a flowchart diagram illustrating a method of processing a video component according to an embodiment of the present invention.

FIG. **8** is a flowchart diagram illustrating a method of processing an audio component according to an embodiment of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

In this document, the terms "comprises", "comprising", "includes", "including" are intended to cover a non-exclusive inclusion. The term video, video signal, video component, or picture component means a signal comprising the luminance information and/or the chrominance (color) information including a picture carrier (or luminance carrier or visual carrier) and/or chrominance carrier/subcarrier. A picture carrier or a visual carrier may carry monochrome (black and white) information. A color or chrominance carrier/subcarrier may carry color or chrominance information. The terms picture and video are equivalent and they may be used alternatively. Likewise, an audio signal and a sound signal are equivalent, and they are modulated on a audio or sound carrier. A TV composite signal may include a video (picture) component and an audio (sound) component. A video component may include the monochrome information and the chrominance information.

Although embodiments of the invention described herein use the exemplary VSB signal (NTSC or National Television Standards Committee system), it will be appreciated that the embodiments may apply to other signals such as PAL (Phase Alternate Line) and multiple versions of SECAM (Sequentiel Couleur avec Memoire) or any other varieties thereof.

FIG. **1**A is a frequency response of a conventional video SAW filter having an IF centered around 44 MHz according to the NTSC analog TV specification. This video filter profile is taken from the SAW filter M3953M data sheet of EPCOS, Inc.

FIG. **1**B is a frequency response of a conventional NTSC audio SAW filter. This audio filter profile is a typical frequency response of the SAW filter M9370M. Both video and audio filters M3953M and M9370M are manufactured by EPCOS, Inc. (www.epcos.com).

FIG. **2** is a TV composite signal according to the NTSC specification. The NTSC channel includes a picture component modulated on a picture carrier frequency, a color component modulated on a color carrier frequency, and sound component modulated on an audio carrier frequency. The TV composite signal represents the baseband TV signal and has a bandwidth of 6 MHz (note that the bandwidth of the SECAM and PAL systems is 8 MHz). The chrominance signals I and Q (U and V in SECAM and PAL) are located at the high frequency end of the luminance signal. And the audio signal is at a higher frequency. Referenced to the picture carrier frequency, the color carrier frequency is at 3.58 MHz (4.43 MHz for the PAL system), and the sound carrier frequency is at 4.5 MHz (5.5 MHz, 6 MHz, or 6.5 MHz for the PAL system) from the picture carrier frequency for the NTSC system. As shown in FIG. **2**, the Nyquist slope frequency response crosses the picture carrier frequency at 0.5 of the energy of the TV composite signal or the TV channel.

FIG. **3** is a block diagram of a conventional TV tuner system **300** that includes a TV tuner **310** coupled to a TV antenna **301** for receiving a radio frequency (RF) signal. The

TV tuner includes a local oscillator for down-mixing the RF signal to an intermediate frequency (IF) signal, which contains a desired TV channel. The IF signal is then provided to an IF demodulator **320** that includes individual video and audio SAW filters as describes above to separate the video signal and the audio signal. The video and audio signals are then individually demodulated and amplified. Thus, the conventional TV tuner requires several SAW filters and analog amplifiers that take up printed circuit board space, consume relatively high power, and have poor separation of the video and audio signals.

FIG. **4** is a conventional block diagram of a demodulator **400** illustrating the use of a video SAW filter and an audio SAW filter. An IF signal from the TV tuner contains a video signal and an audio signal. A video SAW filter **410** passes through the video signal and a sound SAW filter **420** passes through the audio signal. The filtered video and audio signals are then down-converted with respective mixers **412** and **422** that are coupled to a voltage controlled oscillator **430**. The frequency down-converted video signal is routed through a sound trap **416** that suppresses any audio frequency components that may reside in the video signal. And the frequency down-converted audio signal is provided to a FM demodulator **424** that produces an audible sound. Therefore, the conventional TV demodulator requires at least three filters: the video and audio SAW filters and the sound trap bandpass filter.

FIG. **5**A is a block diagram of a TV tuner system **500** according to an embodiment of the present invention. TV receiver system **500** includes an RF tuner **505** that receives an RF signal and frequency down-converts it to an analog IF signal. In an embodiment, the analog IF signal may be either a zero IF, low-IF, or a conventional IF based on the legacy standard (e.g., 36 MHz or 44 MHz). In an embodiment, TV tuner system **500** includes an analog-to-digital converter ADC **510** that converts the analog IF signal to a digital IF signal **512**. Note that down-mixer **512** and digital local oscillator (LO) **514** are only required to convert the digital IF to a digital baseband in the case where RF tuner **505** does not have a zero-IF or super-heterodyne architecture. Down-mixer **512** mixes the digital IF signal with the output of the digital local oscillator **514** to down-convert the digital IF signal to a baseband signal **516**. In an embodiment, the digital local oscillator is implemented as a direct digital frequency synthesizer. The digital local oscillator frequency is selected so that the channel center frequency is down-converted to DC (0 Hz). TV tuner system **500** further includes a video filter **520** and a sound filter **570**.

Video filter **520** replaces the conventional SAW filter in that it passes through the video component and performs the Nyquist slope shaping. Video filter **520** includes a chroma/video filter **525** coupled to an asymmetric filter **530**. Filter **525** may be implemented using a finite impulse response (FIR) filter structure that is configured as a low pass filter for passing through the video component and suppressing the audio component. Asymmetric filter **530** can be implemented as a highpass FIR filter with complex frequency shift for further compensating the Nyquist slope of the video component. In some embodiments, asymmetric filter **530** is further coupled to a digital up-converter **535** that transforms the processed video signal to an intermediate frequency for further video demodulation. The up-conversion may be realized by mixing the output **532** of asymmetric filter **530** with a digital IF signal **542** from a digital local oscillator **540**. Note that the intermediate frequency **542** can be 36 MHz or 44 MHz or other frequencies depending from a subsequent video decoder (not shown).

FIG. **5**B is an exemplary graph **500** illustrating a frequency response of a video/chroma filter **525**, an asymmetric filter **530**, and the resulting frequency response **532** according to an embodiment of the present invention;

Referring back to FIG. **5**A, sound filter **570** includes an audio filter **575** configured to receive digital baseband signal **516**. As described above, the channel center frequency of digital baseband signal **516** is down-converted to DC, i.e., the audio carrier frequency is offset from the channel center by 2.75 MHz for the NTSC system. That means, the digital baseband signal will be mixed with a sound carrier frequency −2.75 MHz so that the audio component is at DC. Note that sound carrier frequency can have other frequency values depending on the standard used. For example, the sound carrier frequency could be offset by 3.25 MHz, or 3.75 MHz, or other frequency amount from the channel center frequency. In that case, sound carrier frequency will be adjusted accordingly so that the audio component is down-converted to DC. The audio component at DC is then processed and output as an audio signal **576**. In an embodiment, the processed digital audio signal **576** can directly be provided to a host processor or audio processor for further processing. In another embodiment, the audio signal **576** may be up-converted to an audio intermediate frequency to provide to an FM demodulator for further processing. In an embodiment, the up-conversion can be implemented with a digital up-converter **580** that digitally multiplies the audio signal **576** with an IF frequency **582** from a digital IF local oscillator **585**. In an embodiment, the digital IF local oscillator **585** may be a direct digital frequency synthesizer.

In an embodiment, video filter **520** and audio filter **570** can be implemented as a hardwired digital circuit such as an application specific integrated circuit (ASIC), a programmable field programmable gate array (FPGA), or a generic or custom digital signal processor running program codes. In an embodiment, IF signals **542** and **582** have the same frequency and share the same direct digital frequency synthesizer.

FIG. **6**A is a simplified block circuit diagram of a baseband filtering device **600** including a video filter **620** and an audio filter **670** according to an embodiment of the present invention. In an embodiment, video filter **620** includes an FIR filter **610** that is implemented as a lowpass filter for extracting the luminance signal from a digital baseband signal **516**. A down-mixer **612** has an input terminal coupled to an output of FIR filter **610** and another input terminal coupled to a picture carrier frequency times −1, and plus 0.75 MHz. In the NTSC system, the picture carrier frequency is −1.75 MHz from the channel center, so the down-converted frequency is −1.75 MHz*(−1)+0.75 MHz=2.5 MHz; it is appreciated that the picture carrier frequency can be any other value, such as −2.25 MHz, or −2.75 MHz used in the PAL system. This picture carrier frequency leads the center of baseband signal shift to the vestigial lower sideband of video component (FIG. **2**). Down-mixer **612** produces a video baseband signal **613** that can further be modified by a highpass filter **614**. In an embodiment, highpass filter **614** is a digital FIR filter having a frequency response for compensation of a Nyquist slope of video signal **613**. The output **615** of highpass filter **614** is shifted back to the normal baseband position by down-mixer **616** with a negative picture carrier frequency minus 0.75 MHz (e.g., −2.5 MHz in NTSC system). In some circumstances, the obtained video signal **618** is up-converted to an IF frequency by an up-converter **535**. In an embodiment, the picture carrier frequency and video IF frequency can be implemented as programmable variables to adjust for different analog TV standards. Although the baseband filtering device is illustrated using discrete functional blocks, the base-

band filtering device can be implemented using a general-purpose or application-specific digital signal processor as described in more detail in late sections (e.g., see FIG. **7**).

Audio filter **670** includes an audio down-mixer **625** that receives digital baseband signal **516** and mixes it with a negative sound carrier frequency to produce a digital audio baseband signal **628** at DC. Audio baseband signal **628** is lowpass filtered by a FIR filter **630** and decimated in a decimator **635** by a factor M to produce a decimated audio signal **637**. Decimated signal **637** is further modified (enhanced) by a subsequent FIR filter **640** with the sample rate of fs/M. FIR filter **640** may be a lowpass filter that further removes unwanted spectrum signals from the decimated audio signal. The modified (or enhanced) audio signal **642** is then interpolated by an interpolator **645** that increases the sampling rate by a factor N and produces an interpolated audio signal **647**. Interpolated signal **647** is further lowpass filtered by an FIR filter **650** that reduces the levels of aliasing signals caused by the interpolation. Filtered audio signal **652** is shifted back to the previous audio location by an up-mixer **660** with the sound carrier frequency. In some circumstances, it is desirable that the audio signal **662** is in an IF band (e.g., 36 or 44 MHz), then the audio signal **662** is up-converted to the IF band by an up-converter **580** that receives the IF frequency from the digital IF local oscillator **585**.

In an embodiment, the decimating factor M and the interpolating factor N are positive integer. In another embodiment, decimating factor M and interpolating factor have the same value. In an embodiment, the sound carrier frequency, the picture carrier frequency, and the IF local oscillator frequency can be implemented as programmable parameters that are adjusted for different analog TV standards. In an embodiment, picture carrier frequency, sound carrier frequency, and IF frequency are digital signals that are generated using numerically controlled oscillators. They can be implemented using common direct digital frequency synthesizers (DDFS), or simple look-up tables with fixed point entries of several sinusoidal waves at desired frequencies.

In an embodiment, mixer pairs **612**/**616**, and **625**/**660** may use the same local oscillator for each pair, where the local oscillator can be a digital direct frequency synthesizer. And the IF mixers **535** and **580** for the respective filtered video and audio components may also share one digital direct frequency synthesizer.

As the filter device disclosed in the present invention is purely digital, it can be designed using any hardware description language such as Verilog or VHDL. They also can be simulated using any computer aided design tools such as Matlab or C model simulation. And the simulation model can also be synthesized using any logic synthesis tools and implemented as an integrated circuit device using any semiconductor process. Those skilled in the art will readily observe that numerous modifications and alterations of the filter device may be made based on the teachings of the present invention.

FIG. **6**B is an exemplary graph illustrating frequency response waveforms at different stages of a digital audio SAW filter according to an embodiment of the present invention. The graph will be described together with the functional blocks in FIG. **6**A. Curves **630** and **650** show an exemplary frequency response of the respective filters **630** and **650**. As described above, FIR filter **630** can be a lowpass filter that passes the audio signal **628**. Curve **640** is an exemplary frequency response of FIR filter **640** that further suppresses picture components that may be present in the audio signal. In an embodiment, FIR filters **630** and **650** may be identical. Curve **652** is the resulting frequency response of filters **630**, **640**, and **650** that are connected in series.

In an embodiment, a decimator **635** may be interposed between FIR filters **630** and **640**, and an interpolator **345** is interposed between FIR filters **640** and **650** (FIG. **6**A). The resulting frequency response (FIG. **6**B) does not change as illustrated in curve **652** shown in FIG. **6**B.

FIG. **7** is a flowchart diagram **700** illustrating the steps of a method **700** for processing a video component in a digital baseband according to an embodiment of the present invention. Referring to FIG. **6**, the baseband filter device **600** receives the digital baseband signal having a channel center at DC. In step **702**, the baseband filter device receives the digital baseband signal having a channel center at DC. The digital baseband signal includes a video component and an audio component. In step **704**, the video component in the digital baseband signal is filtered using a lowpass filter. The low pass filter may be implemented using a finite impulse response (FIR) filter. In step **706**, the filtered video component is frequency up-shifted by multiplying the filtered video component with a frequency corresponding to the absolute value of picture carrier frequency plus 0.75 MHz. In step **708**, the frequency up-shifted video component is Nyquist filtered to compensate for the Nyquist slope. In an embodiment, the Nyquist slope compensation is performed using a FIR filter having a highpass characteristic. In step **710**, the Nyquist compensated video component is frequency down-shifted by a frequency amount significantly equal to the absolute value of picture carrier frequency plus 0.75 MHz. In step **712**, the Nyquist compensated video component is up-converted to an intermediate frequency to provide a video decoder for further processing.

FIG. **8** is a flowchart diagram of a method **800** for processing an audio component according to an embodiment of the present invention. As described above, when the channel center is down-shifted to DC, the audio carrier is offset from DC by a frequency offset, e.g., 2.75 MHz in the NTSC system. In step **702** (as shown in FIG. **7**), the baseband filter device receives the digital baseband signal having the video component and the audio component. The video component is filtered using a lowpass FIR filter (step **704** in FIG. **7**). Here, method **800** frequency down-shifts the digital baseband signal to DC by mixing the digital baseband signal with a sound carrier frequency to obtain the audio component at DC (step **804**). In step **806**, the audio component at DC is filtered and decimated to remove unwanted signals such as the video component. In step **808**, the decimated audio component is further processed using a digital filter. In an embodiment, a finite impulse response (FIR) lowpass filter may be used to further suppress the video component and other unwanted signals. In step **810**, the processed audio component is interpolated and filtered to produce a digital audio output. In step **812**, the digital audio output may be up-converted to an intermediate frequency for further processing at an FM demodulator.

The methods described above may be implemented, for example, by using a general-purpose or custom digital signal processor to execute a sequence of machine-readable instructions. These instructions may reside in various types of signal-bearing media. In an embodiment, the signal-bearing medium may comprise RAM (SRAM, DRAM), ROM, EPROM, EEPROM, or Flash memory. In an embodiment, the machine readable instructions may comprise lines of C, or C++, or other suitable programming or coding languages commonly used by those skilled in the art.

While the embodiments and advantages of the present invention have been described for a TV signal based on the NTSC standard, it will be appreciated by those skilled in the art that the disclosure may equally be applied to TV signals of

different standards such as PAL and SECAM. Thus, the disclosure and description herein are purely illustrative and are not intended to be in any sense limiting.

What is claimed is:

1. A filter for processing a digital television (TV) composite signal having a video component and an audio component, the filter comprising:

an input terminal for receiving the digital TV composite signal;

a first lowpass filter coupled to the input terminal, the first lowpass filter being configured to pass through the video component;

a digital video filter coupled to the lowpass filter and being configured to process the video component, the digital video filter comprising:

a first mixer configured to frequency shift the video component by a first frequency offset;

a digital highpass filter responsive to the first mixer and configured to compensate a Nyquist slope of the first frequency-shifted video component; and

a second mixer responsive to the digital highpass filter; said first mixer, said digital highpass filter and said second mixer being coupled in series;

a third mixer configured to frequency shift the digital TV composite signal by a first frequency amount; and

a digital audio filter configured to receive the frequency shifted digital TV composite signal.

2. The filter of claim **1**, wherein the first lowpass filter comprises a first finite impulse response (FIR) filter.

3. The filter of claim **1**, wherein:

the second mixer mixes the Nyquist compensated video component by a second frequency offset to obtain a second frequency-shifted and Nyquist compensated video component.

4. The filter of claim **3**, wherein the sum of the first frequency offset and the second frequency offset is substantially equal to zero.

5. The filter of claim **3**, wherein the first and second frequency offsets are associated with a picture carrier frequency and a third frequency offset.

6. The filter of claim **5**, wherein the third frequency offset is about 0.75 MHz.

7. The filter of claim **1**, wherein the digital audio filter comprises:

a second lowpass filter configured to pass through the audio component;

a decimator configured to reduce a first sampling rate of the audio component by a factor M;

a second FIR filter configured to enhance the reduced sampling rate audio component;

an interpolator configure to increase the enhanced and sampling-rate audio reduced audio component by a factor N; and

a third FIR filter configured to output an audio signal.

8. The filter of claim **7**, wherein the factors M and N are positive integer.

9. The filter of claim **7**, wherein the factors M and N are equal.

10. The filter of claim **7**, wherein the digital audio filter further comprises a fourth mixer configured to frequency shift the audio signal by a second frequency amount.

11. The filter of claim **10**, wherein the second frequency amount is associated with a sound carrier frequency.

12. The filter of claim **7**, wherein the digital audio filter further comprises a first up-converter configured to up-convert the audio signal to an audio intermediate frequency.

13. The filter of claim **1**, wherein the first frequency amount is associated with a sound carrier frequency.

14. The filter of claim **1** further comprising a second up-converter configured to up-convert the processed video component to a video intermediate frequency.

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